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EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act requires each state to develop Total Maximum Daily Loads (TMDLs) for surface waters that do not meet and maintain applicable water quality standards. A TMDL establishes the amount of a given pollutant that the waterbody can withstand without creating an impairment of that surface water's designated use. The TMDL by definition (40 CFR Part 130) is the sum of all point and non-point sources with the inclusion of a margin of safety and natural background considerations.

Boulder Creek, located near Bagdad, AZ, in west central Yavapai County, appears on the Arizona Department of Environmental Quality's1998 List of Water Quality Limited Waters for exceedances of surface water quality standards for arsenic, beryllium, copper, lead, manganese, and zinc. Specific surface water quality standards for these parameters are listed in Title 18, Chapter 11 of the Arizona Administrative Code. For this TMDL investigation, samples were collected at locations to provide definition of pollutant sources and the extent of impairment. Beryllium, lead, and manganese results were below water quality standards for the whole reach.

The sources of pollutants are three tailings piles, the upper tailings pile, the middle tailings pile, and the lower tailings pile, and an adit discharge from the abandoned Hillside Mine. The tailings piles are located on land owned by three different entities: Bureau of Land Management (BLM), private, and State of Arizona, respectively. In October 1999, BLM hired a contractor to conduct a site characterization of the tailings piles in preparation for remediation efforts. BLM and its contractors drafted a remediation/reclamation plan for the upper and middle tailings piles. In early 2001, the U.S Environmental Protection Agency (EPA) became involved in remediation by offering financial assistance and by offering to manage the project under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Currently, the Hillside Mine is not on the National Priorities List (NPL), and its non-NPL status is as a "removal only" site. In late summer 2001, EPA entered discussions with the private landowner to review the landowner's proposal to reprocess and remediate the upper and middle tailings piles. Since then, the owners of the middle tailings pile have rescinded their offer to reprocess the tailings piles and are discussing reclamation possibilities with EPA. BLM is moving forward on their plans to remediate the upper tailings pile. The Arizona Department of Environmental Quality (ADEQ) is assisting the Arizona State Land Department in applying for a federal 319(h) grant to develop and start a reclamation project for the lower tailings pile.

LIST OF ABBREVIATIONS

AAC	Arizona Administrative Code
A&Ww	Aquatic and Wildlife, warmwater
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
AGFD	Arizona Game and Fish Department
AgI	Agriculture Irrigation
AgL	Agriculture Livestock Watering
ALRIS	Arizona Land Resource Information System
ARS	Arizona Revised Statutes
AWPF	Arizona Water Protection Fund
BLM	Bureau of Land Management
BMP	Best Management Practices
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
EPA	Environmental Protection Agency
F	Fahrenheit
FBC	Full Body Contact
FC	Fish Consumption
ft MSL	Feet above Mean Sea Level
GIS	Geographic Informational Systems
mg/L	Milligrams per Liter
MGD	Millions of Gallons per Day
MOS	Margin Of Safety
NPL	National Priorities List
TMDL	Total Maximum Daily Load
USFS	United States Forest Service
USGS	United States Geological Survey
WLA	Waste Load Allocation

1 BACKGROUND

1.1 Geography

Boulder Creek is located in western Yavapai County, near Bagdad, AZ. It is predominantly an intermittent watercourse which flows 37 miles from its headwaters near Camp Wood Mountain, 7000± feet above mean sea level (ft MSL), to its confluence with Burro Creek at 2460± ft MSL. The listed reach, HUC# 15030202-005, runs from the confluence with Wilder Creek to just above the confluence with Burro Creek (Figure 1-1).

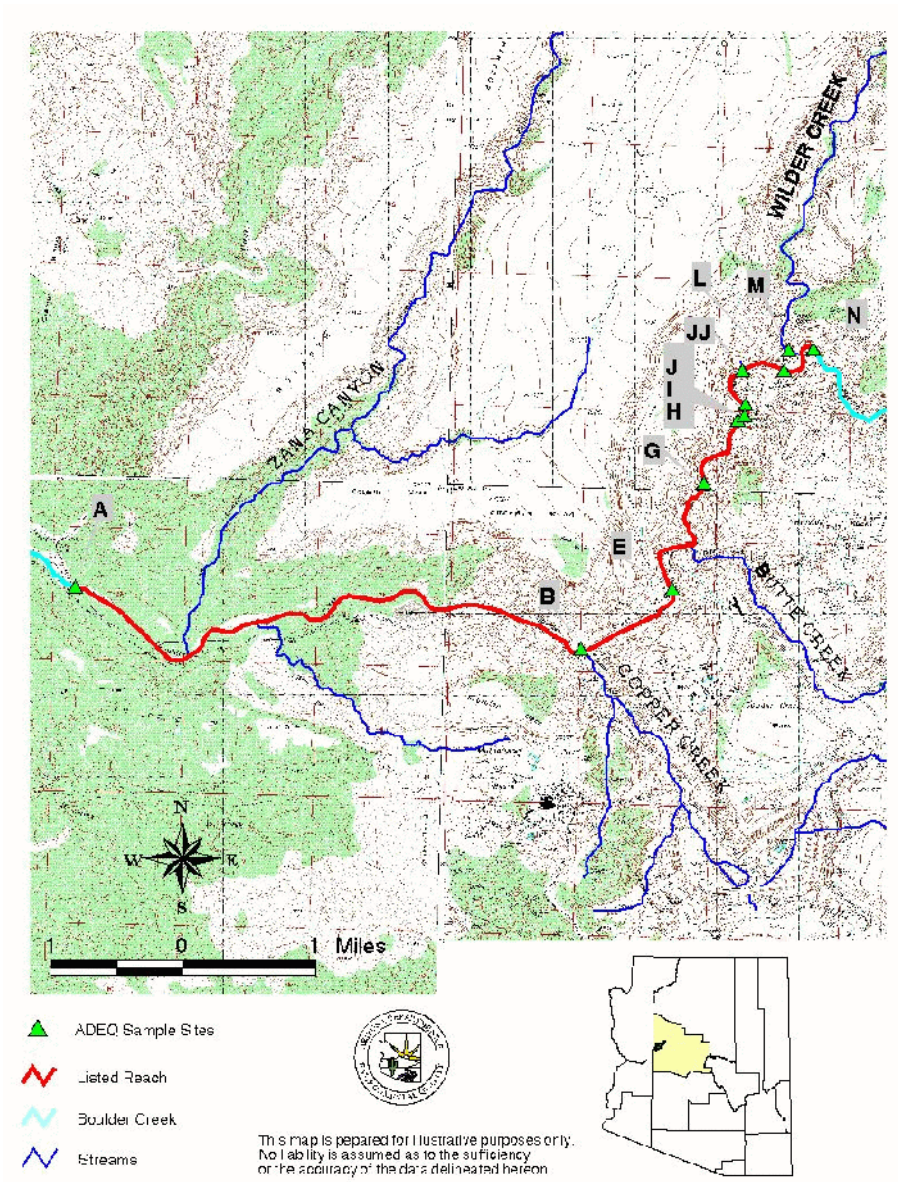

Figure 1-1 Project Area

1.2 Climatology

The listed reach lies at elevations between 3150 ft MSL and 2460 ft MSL. A meteorological station in Bagdad has recorded precipitation data which are representative of the conditions for the Boulder Creek watershed. The station is located 3704 ft MSL and it has recorded daily precipitation continuously from January 1928. The average annual precipitation over the period 1928 to 2000 was 15.0 inches. Annual precipitation ranged from a low of 3.0 inches in 1956 to 29.2 inches in 1978 (Tetra Tech, 2002). Daily temperature data for the period 1929 to the present is also available from this station. The average annual temperature for the Boulder Creek area as measured at Bagdad is 63.1E Fahrenheit (F), varying from an average monthly temperature of 45.7E F in January to 82.7E F in July (Tetra Tech, 2001).

1.3 Hydrology

The Boulder Creek watershed drains approximately 138 square miles. Flow is dependent on winter storms and spring snowmelt. Boulder Creek flows mainly from late October or early November until late May, with the highest flows occurring from late January through early March (Figure 1-2). From June until early November or December, Boulder Creek consists of a number of independent pools separated by long stretches of dry streambed.

Figure 1-2 Boulder Creek's flow regimes are contrasted in these two pictures. The top picture is from February 2001, and the bottom one is the same location in November of the same year.

There are no USGS or county stream gage stations on Boulder Creek. The nearest USGS gage, #09424447, is located on Burro Creek at the US Highway 93 Bridge near Bagdad, AZ. Daily and monthly streamflow data are available at this location from August 1980 through February 1994 (Tetra Tech, 2002). Stream flow measurements were taken by ADEQ at select sampling locations in support of this TMDL investigation measured flow ranged from 0.01 cfs to 11.6 cfs. Flow was not measured in February 2001 due to high flow conditions. Estimated flow at this time was >50cfs. There was no measurable flow from May 2001 until December 2001, except at site H where the adit discharge provides minor flow. These measurements are shown in Appendix A.

1.4 Geology

The geology of the project area is complex. The rocks exposed in this region are predominantly of Precambrian and Tertiary age. The older Precambrian rocks of this area consist of metamorphosed volcanic and sedimentary rocks that have been intruded and deformed by plutons of granitic to gabbroic composition. These were later covered by late Cretaceous or early Tertiary rhyolite tuffs and subsequently intruded by rhyolite dikes and quartz monzonite stocks and related dikes. Quaternary lava flows were later carved into the mesas present today (Anderson *et al.* 1955).

In the project area, Boulder Creek cuts a steep canyon through mesas capped with Quaternary basalt flows and the underlying basement rock. In the vicinity of the abandoned Hillside Mine, the creek cuts through a section of the Hillside mica schist, a metamorphosed sandstone and shale complex. The schist is intruded by the Lawler Peak granite to the west. Small sills and dikes of granodiorite gneiss and pegmatite dikes also cut through the schist. In the vicinity of the LTP, the creek flows over the Butte Falls tuff, a bedded, water lain, metamorphosed (probably from the Lawler Peak intrusion) tuff that grades upward into the Hillside mica schist (Anderson *et al.* 1955). Shortly after flowing over Butte Falls, in the vicinity of Butte Creek, the gradient decreases and the topography is less steep and constrictive. Here, Boulder Creek cuts through, and flows over, outcrops of gabbro, Gila conglomerate, and Quaternary gravels (Anderson *et al.* 1955).

In the project area, the minerals of economic importance include gold, silver, sphalerite, galena, chalcopyrite, and pyrite (Anderson *et al.* 1955). The minerals are found in vein deposits that parallel the hillside fault.

1.5 Vegetation/Wildlife

Vegetative communities range from Sonoran Desert and chaparral at the lower and mid elevations, through juniper and oak woodland, to Ponderosa pine and Douglas fir at higher elevations near the headwaters. The listed reach runs through the mid to lower elevations. Wildlife in the area include deer, javelina, mountain lions, small mammals, and various bird species. Boulder Creek is home to a variety of native fish, most notably *Gila robusta* (Roundtail Chub) and *Catostomus insignis* (Sonora Sucker). There have been no federally threatened or endangered fish species sighted in Boulder Creek (Unmack, 2002).

1.6 Land Ownership/ Use

The majority of the land in the project area is private and state trust land (Figure 1- 3). A small portion is BLM land. Land use is predominantly ranching, mining, and open range.

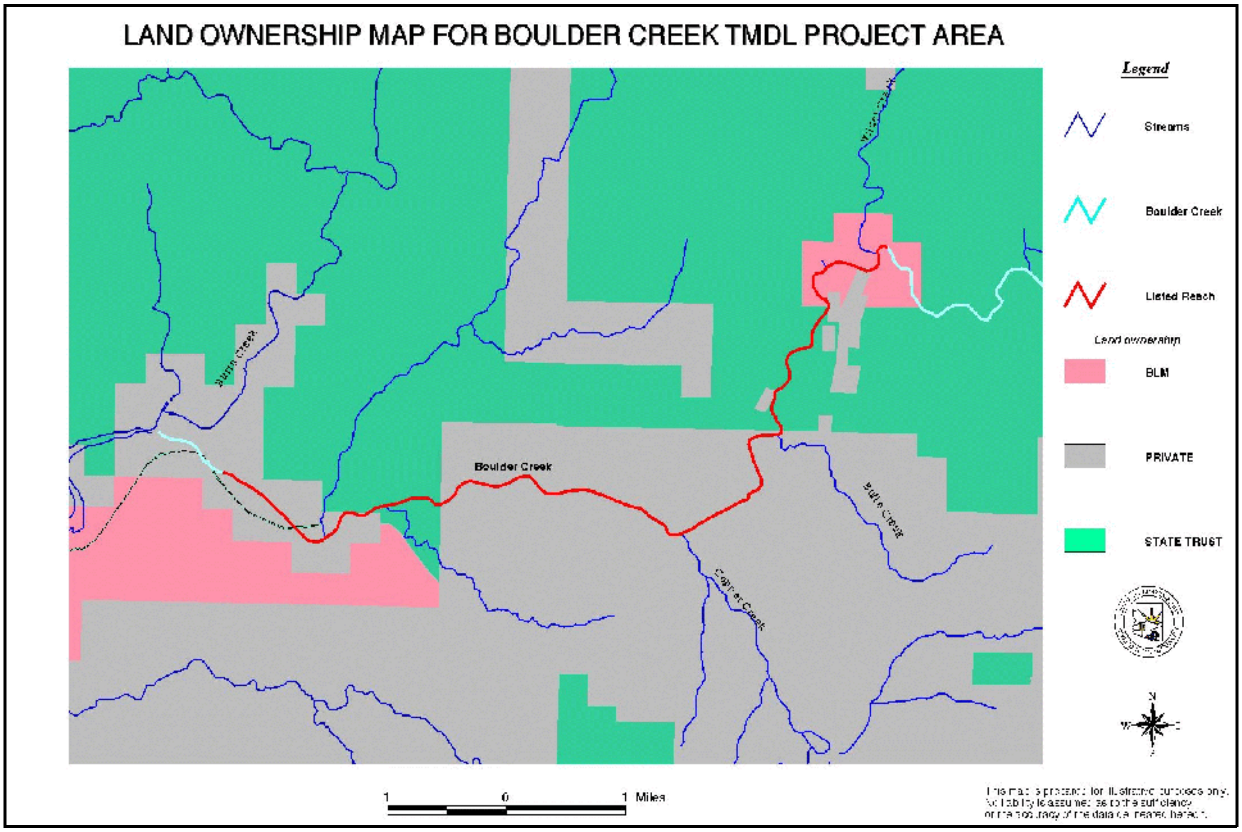

Figure 1-3

2 NUMERIC TARGETS

2.1 Clean Water Act Section 303(d) List

Section 303(d) of the Clean Water Act requires states to compile a list of surface waterbodies that do not meet applicable water quality standards. TMDLs must be developed for every waterbody on the 303(d) List. TMDLs set the amount of given pollutant(s) that the waterbody can withstand without creating an impairment of that surface water's designated use(s).

Boulder Creek appears on Arizona's 1998 list of water quality limited waters due to exceedances of surface water quality standards for arsenic, beryllium, copper, lead, manganese, and zinc (ADEQ, 2000). The listing was based on 9 samples collected in the vicinity of the abandoned Hillside Mine in October 1992, by ADEQ. These data are summarized in Appendix B.

2.2 Beneficial Use Designations

ADEQ codifies water quality regulations in Title 18, Chapter 11 of the Arizona Administrative Code (AAC) (ADEQ, 1996). Designated beneficial uses, such as consumption, recreation, agriculture, and aquatic biota, are described in Section R18-11-104 of the AAC and are listed for specific surface waters in Appendix B of AAC R18-11. Boulder Creek is currently protected along reach HUC# 15030202-005 for the following designated uses: Aquatic and Wildlife warm water fishery (A&Ww); Fish Consumption (FC); Full Body Contact (FBC); Agricultural Livestock Watering (AgL); and Agricultural Irrigation (AgI).

2.3 Applicable Water Quality Standards

Title 18, Chapter 11 of the AAC defines water quality standards for surface waters as a numeric constituent concentration or a narrative statement representing a quality of water that supports a designated use(s) of the waterbody. Table 2-1 shows the applicable water quality standards for Boulder Creek. The most stringent standards for each designated use are indicated by the bold highlight. The A&Ww water quality standards for copper, lead, and zinc are hardness dependent.

Table 2-1 ADEQ Use Designations and Corresponding Water Quality Standards

	Fish Consumption	Full Body Contact	Agricultural Irrigation	Agricultural Livestock Watering	Aquatic & Wildlife warmwater (acute)	Aquatic & Wildlife warmwater (chronic)
Arsenic, Fg/L	1,450 T	**50 T**	2,000 T	200 T	360 D	190 D
Beryllium, Fg/L	1130	2800	NNS	NNS	65 D	**5.3 D**
Copper, Fg/L	NNS	1,300 D	5,000 T	500 T	(A)* [3.64 - 49.62] D	**(E)* [2.74 - 29.28] D**
Lead, Fg/L	NNS	15	10,000 T	100 T	(B)* [13.9 - 280.9] D	**(F) * [0.54 - 10.94] D**
Manganese, Fg/L	NNS	196,000	**10,000 T**	NNS	NNS	NNS
Zinc, Fg/L	69,000	420,000	10,000 T	25,000 T	(C)* [36.2 - 379.3] D	**(J)* [36.2 - 379.3] D**

Notes:

T = Total recoverable metal concentration

D = Dissolved metal concentration

NNS = No numerical standard

*A = Aquatic & Wildlife warmwater (acute) standard for Copper: e(0.9422 [ln(hardness)] - 1.7) * 0.96*

*B = Aquatic & Wildlife warmwater (acute) standard for Lead: e(1.2730 [ln(hardness)] - 1.460) * (1.46203 - [ln (hardness)] * 0.145712)*

*C = Aquatic & Wildlife warmwater (acute) standard for Zinc: e(0.8473 [ln(hardness)] + 0.884) * 0.978*

*E = Aquatic & Wildlife warmwater (chronic) standard for Copper: e(0.0845 [ln(hardness)] - 1.702) * 0.96*

*F = Aquatic & Wildlife warmwater (chronic) standard for Lead: e(1.2730 [ln(hardness)] - 4.705) * (1.46203 - ln (hardness) * 0.145712)*

*J = Aquatic & Wildlife warmwater (chronic) standard for Zinc: e(0.008473 [ln(hardness) + 0.884) * 0.978*

Note: Hardness, expressed as mg/L $CaCO_3$, inserted into the equation where it says "Hardness". Hardness for the Aquatic & Wildlife warmwater standard is based on the hardness of the receiving water body from a sample taken at the same time that the sample for the metal is taken, except that the hardness may not be below 25 mg/l nor exceed 400 mg/L as $CaCO_3$. The numbers in the brackets represent the range of values based on hardness values from 25-400 mg/L as $CaCO_3$.

3 SOURCE ASSESSMENT

A wide range of data and information was used to develop these TMDLs. This included physiographic data which describes the physical conditions of the watershed, environmental data that identify potential pollutant sources and their contributions, and in stream water quality monitoring data. The in-stream monitoring data used to determine impairment for the 303(d) listing were collected on October 22, 1992 in support of the goals of other programs. These results were insufficient to isolate sources or to characterize the impacts of weather, physical conditions or seasonal variation on the stream water quality. As part of this project, the ADEQ TMDL Program collected data specific to the goals of source identification and TMDL calculation. Water quality samples were collected on a monthly basis from October 2000 until August 2001 at 11 sites to systematically monitor conditions along the listed reach to determine the extent, frequency and conditions under which impairment occurs as well as identify background water quality. Sites were established at the beginning and end of the reach; upstream and downstream of potential point and non point sources; and at several other accessible monitoring locations. Site locations are shown on Figure 1-1.

There are no USGS or County stream gage stations on Boulder Creek. The nearest USGS gage 09424447 is located on Burro Creek at the old US Highway 93 Bridge near Bagdad, Arizona (Figure

3-1). Daily and monthly streamflow data is available at this location from August 1980 through February 1994. Data from this station was used in estimating seasonal flow variations and the response to precipitation within the Boulder Creek Watershed. Table 3-2 presents a summary of the flow data available for this location.

Streamflow data is also available from USGS at a few sampling locations on and near Boulder Creek. Streamflows at these locations were estimated during monthly sampling events between 1977 through 1979. In addition, instantaneous stream flow measurements are available from the early 1990's at two locations on Boulder Creek and stream flow measurements or estimates were also derived by ADEQ during 2000 and 2001 water quality sampling events on Boulder Creek

Additional observed data from four other sources (Bureau of Land Management (BLM) study of Burro Creek in 1982-83; ADEQ sampling near Hillside Mine in 1992/93; USGS sampling in Boulder Creek in 1977-79; samples collected by BLM in 2000 at and near the Hillside Mine tailing piles were also used to support water quality analysis for the Boulder Creek watershed. The water quality data from ADEQ is summarized in Appendix A.

3.1 Segmenting Boulder Creek

Data from the ADEQ TMDL sampling effort are presented in Appendix A. Sample results show that portions of the listed reach were not impaired at the times sampling occurred. The model used in this investigation, in most cases, corroborated the identification of non-impaired stretches. The model took into account historic sample results as well as the sample results generated through this investigation.

Based on field observation and modeling, ADEQ supports removing certain pollutants ("delisting") from specific segments of the stream. Tables 3-1, 3-2, and 3-3 provide the sampling results which support delisting beryllium, lead, and manganese from Wilder Creek to Burro Creek and copper and zinc from Wilder Creek to Copper Creek. ADEQ also supports delisting arsenic from an unnamed tributary of Boulder, just upstream of Zana Canyon, to Burro Creek. Segmentation at this location was chosen based on the location of sampling points and it is supported through modeling. These delist decisions are based on the new WQS standards approved by EPA on November 13, 2002.

For lead, the laboratory reporting level was at times higher than the calculated water quality standard (based on hardness at time of sampling). This made direct comparison with the water quality standard impossible in some cases. However, the modeling results, based on input of one-half the laboratory reporting limit of 5ug/L, resulted in no projected exceedances of the surface water quality conditions under all flow regimes. Based on these two factors, ADEQ proposes to delist lead from the entire reach, Wilder Creek to Burro Creek.

Table 3-1 Summary of Delist Data From Wilder Creek to Butte Creek

Site	Parameter	# Samples	Mean (Fg/L)	Min (Fg/L)	Max (Fg/L)	Standard (Fg/L)	# of Exceedances
N	Be (D)	8	<2	<2	<2	5.3	0
L	Be (D)	4	<2	<2	<2	5.3	0
JJ	Be (D)	4	<3.0	<2	12	5.3	1
J	Be (D)	6	<2	<2	<2	5.3	0
H	Be (D)	13	<2	<2	<2	5.3	0
G	Be (D)	7	<2	<2	<2	5.3	0
N	Pb (D)	8	<5	<5	<5	0.84-4.52[1]	U
L	Pb (D)	4	<5	<5	<5	1.31-6.15[1]	U
JJ	Pb (D)	4	<5	<5	<5	2.38-10.94[1]	U
J	Pb (D)	6	<5	<5	<5	1.23-5.31[1]	U
H	Pb (D)	13	<5	<5	<20	1.23-10.94[1]	U
G	Pb (D)	7	<5	<5	<5	1.23-5.52[1]	U
N	Mn (T)	8	22.5	<20	70	10,000	0
L	Mn (T)	4	17.5	<20	40	10,000	0
JJ	Mn (T)	4	5942.5	30	23,400	10,000	1
J	Mn (T)	6	61.7	30	120	10,000	0
H	Mn (T)	13	2835.4	40	11,800	10,000	2
G	Mn (T)	7	130	50	260	10,000	0

% Exceedances: Be, 2%; Mn, 7%; Pb; 0%
1: Based on hardness values taken at time of sampling.
U: Laboratory reporting level at or higher than the calculated water quality standard making direct comparison difficult.

Table 3-2 Summary of Delist Data From Butte Creek to Copper Creek

Site	Parameter	# Samples	Mean (Fg/L)	Min (Fg/L)	Max (Fg/L)	Standard (Fg/L)	# of Exceedances
E	Be (D)	6	<2	<2	<2	5.3	0
E	Mn (T)	6	81.7	40	160	10,000	0
E	Pb (D)	6	<5	<5	<5	1.36-3.99[1]	U

%Exceedances: Be, 0%; Mn, 0%; Pb, 0%
1: Based on hardness values taken at time of sampling.
U: Laboratory reporting level at or higher than the calculated water quality standard making direct comparison difficult.

Table 3-3 Summary of Delist Data From Copper Creek to Burro Creek

Site	Parameter	# Samples	Mean (Fg/L)	Min (Fg/L)	Max (Fg/L)	Standard (Fg/L)	# of Exceedances
A	Be (D)	6	<2	<2	<2	5.3	0
B	Be (D)	7	<2	<2	<2	5.3	0
A	Cu (D)	6	<15	<15	<15	6-24[1]	U
B	Cu (D)	7	<15	<15	<15	6-19[1]	U
A	Mn (T)	6	105.0	<20	510	10,000	0
B	Mn (T)	7	44.3	<20	150	10,000	0
A	Pb (D)	6	<5	<5	<5	1.44-8.69[1]	U
B	Pb (D)	7	<5	<5	<5	1.44-6.49[1]	U
A	Zn (D)	6	5.0	<20	30	76-314[1]	0
B	Zn (D)	7	17.1	<20	50	76-248[1]	0

% Exceedances: Be, 0%; Mn, 0%; Pb, 0% Zn, 0%
1: Based on hardness values taken at time of sampling.
U: Laboratory reporting level at or higher than the calculated water quality standard making direct comparison difficult.

3.2 Hillside Mine

The Hillside Mine is an abandoned gold-silver-zinc-lead mine and mill site. The mine was operated from 1887 to 1951. The main shaft was sunk along the Hillside vein at the site of the current MTP. The Hillside vein is a typical quartz-sulfide fissure vein that follows the Hillside fault. The vein was worked approximately 2,700 ft. along strike and 900 ft. down dip (Anderson *et al.* 1955). Gold, silver, and lead were the sole metals produced from 1887 to 1933. Copper and zinc production began in the mid 1930s. Copper was a minor constituent, contributing approximately 1% of the value of the metals produced (Anderson *et al.* 1955). A custom mill built in 1946 in the vicinity of the upper tailings pile treated ore from the Hillside Mine and other custom ores, such as tungsten, copper, and gold, from nearby mines. The mill operated until around 1954.

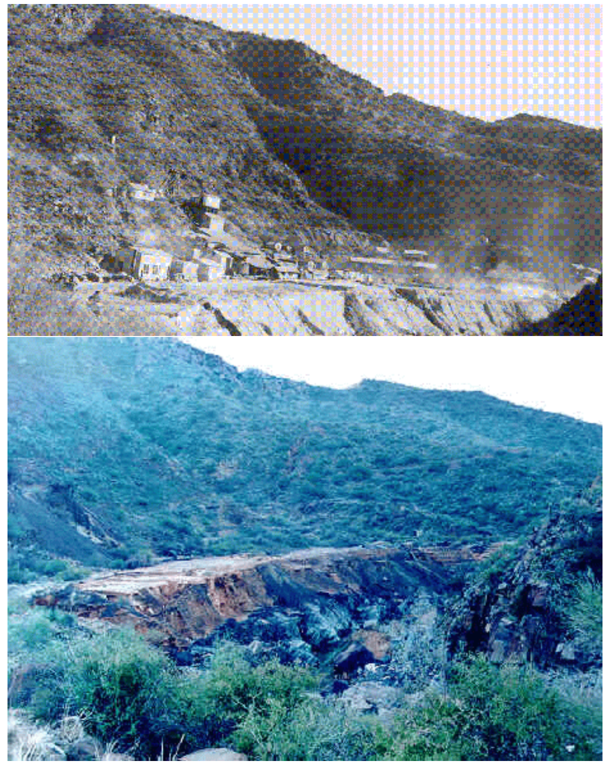

Figure 3-1 The top photo (courtesy of Arizona Department of Mines and Mineral Resources) shows the Hillside mine in January 1940. The bottom photo is the same location in January 2001.

The site now consists of the head frame, primary and secondary shafts, three tailings piles (Figure 3-2), and the former mill site. Massive sulfides ore in mine tailing are being weathered and oxidized at an accelerated rate due to a reaction with water ans oxygen. This chemical reaction produces high concentration of metals and acidic water, which eventually leach into the Boulder Creek. (Tetra Tech, 2002)

There is also a discharge that emanates from a collapsed adit near the toe of the middle tailings pile. The adit has a continuous discharge, approximately 5 gpm and is a main source of dissolved metals including arsenic, manganese, and zinc.

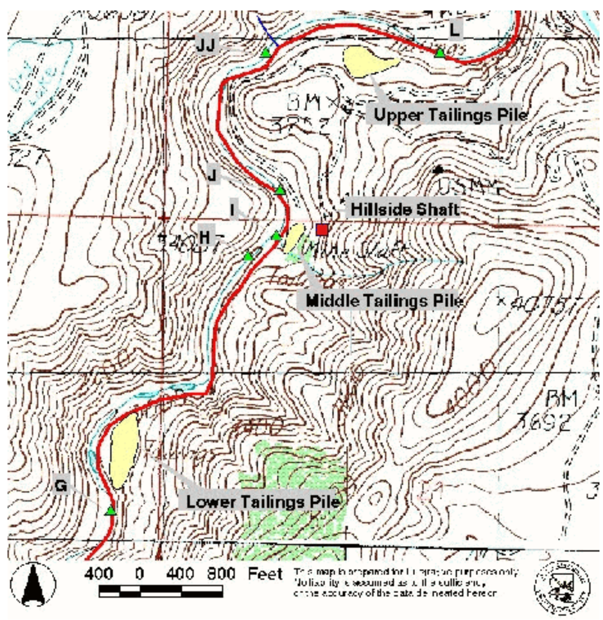

Figure 3-2 Overview of Hillside Mine Complex.

3.2.1 Upper Tailings Pile

The upper tailings pile is located on BLM land and is composed of two piles in the vicinity of the custom mill site (Figure 3-3)[1]. The eastern lobe covers approximately 1.72 acres and has an approximate volume of 26,362 cubic yards. The western lobe covers approximately 0.91 acres and has an approximate volume of 17,618 cubic yards (BLM, 2000). The mill, located immediately south of the tailings pile, processed ores from the Hillside and custom ores from other mines in the area.

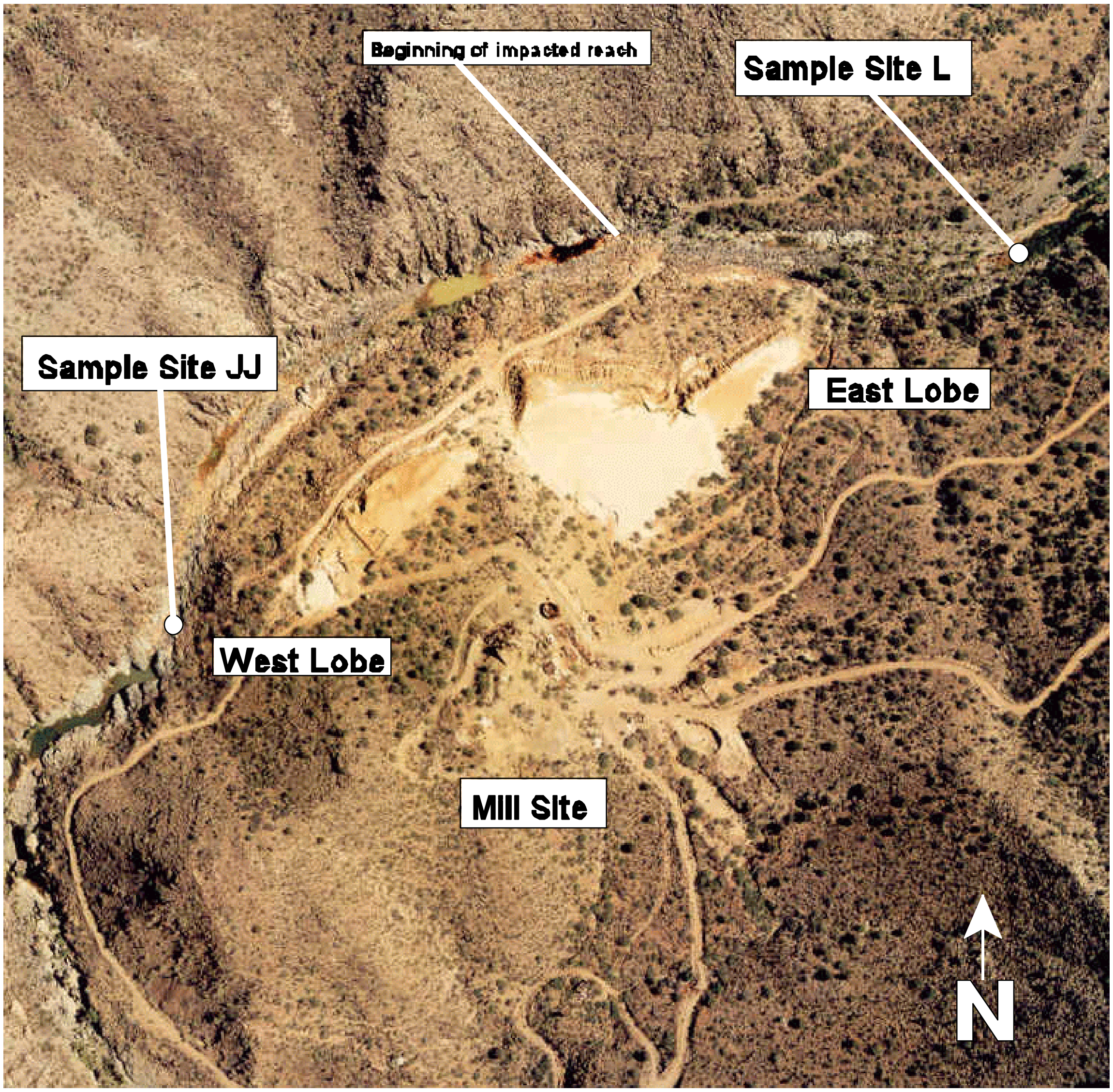

Figure 3-3 Upper Tailings Pile and Mill Site (photo courtesy of BLM, July 1999)

[1]Sample sites referenced in the images correspond to the data in Appendix A.

3.2.2 Middle Tailings Pile

The middle tailings pile is located on patented mining claims at the site of the main shaft of the Hillside Mine (Figure 3-4). This property is owned by KFX Building Company, Inc. This tailings pile covers approximately 1.72 acres and has an approximate volume of 41,624 cubic yards (BLM, 2000).

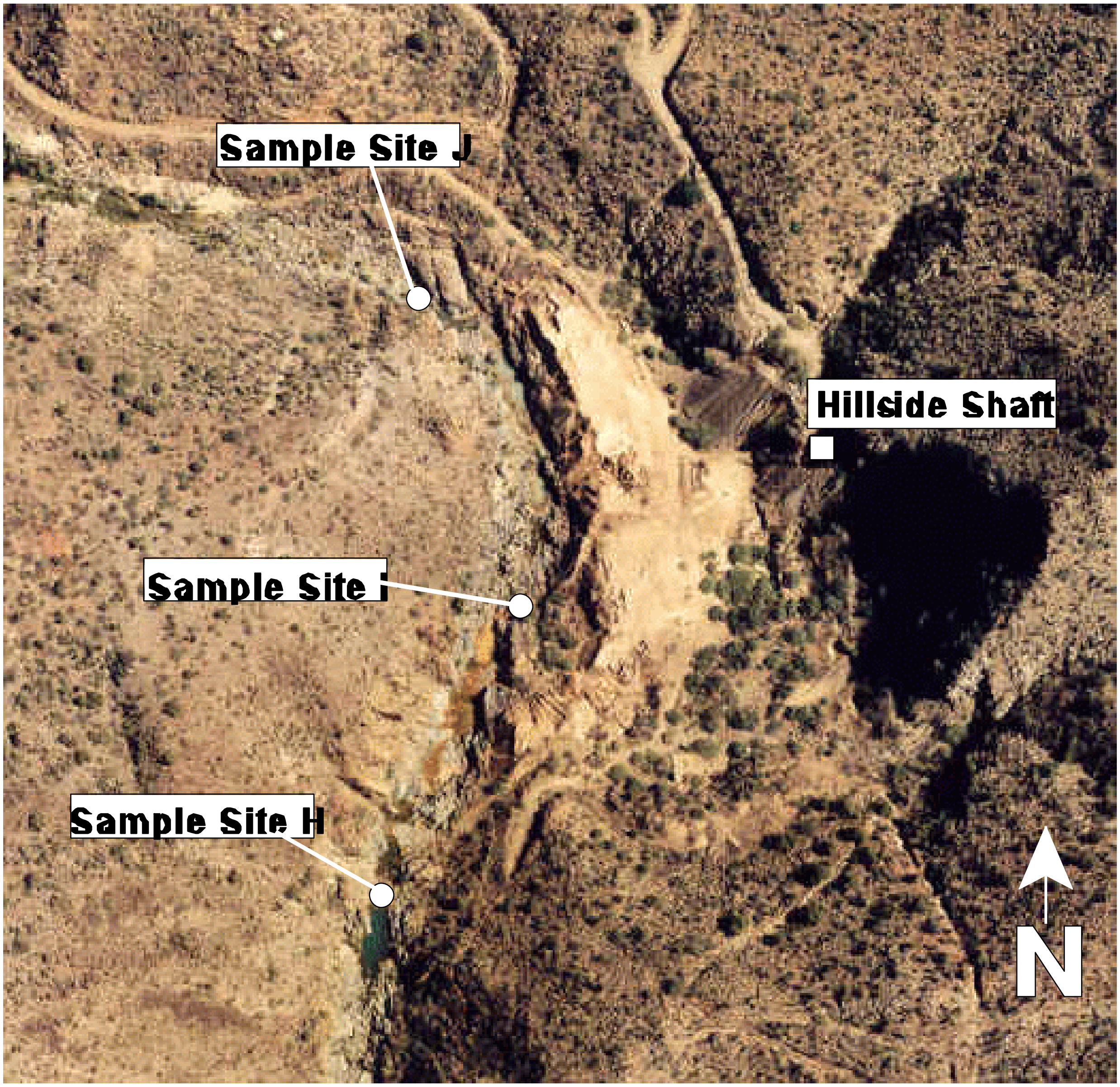

Figure 3-4 Middle Tailings Pile (photo courtesy of BLM, July 1999)

3.2.3 Lower Tailings Pile

The lower tailings pile is located on State Trust land approximately 0.6 stream miles downstream of the middle tailings pile (Figure 3-5). The lower tailings pile covers approximately 2.41 acres and has an approximate volume of 54,434 cubic yards (BLM, 2000). The tailings materials were slurried in a pipeline from the Hillside Mine to this location.

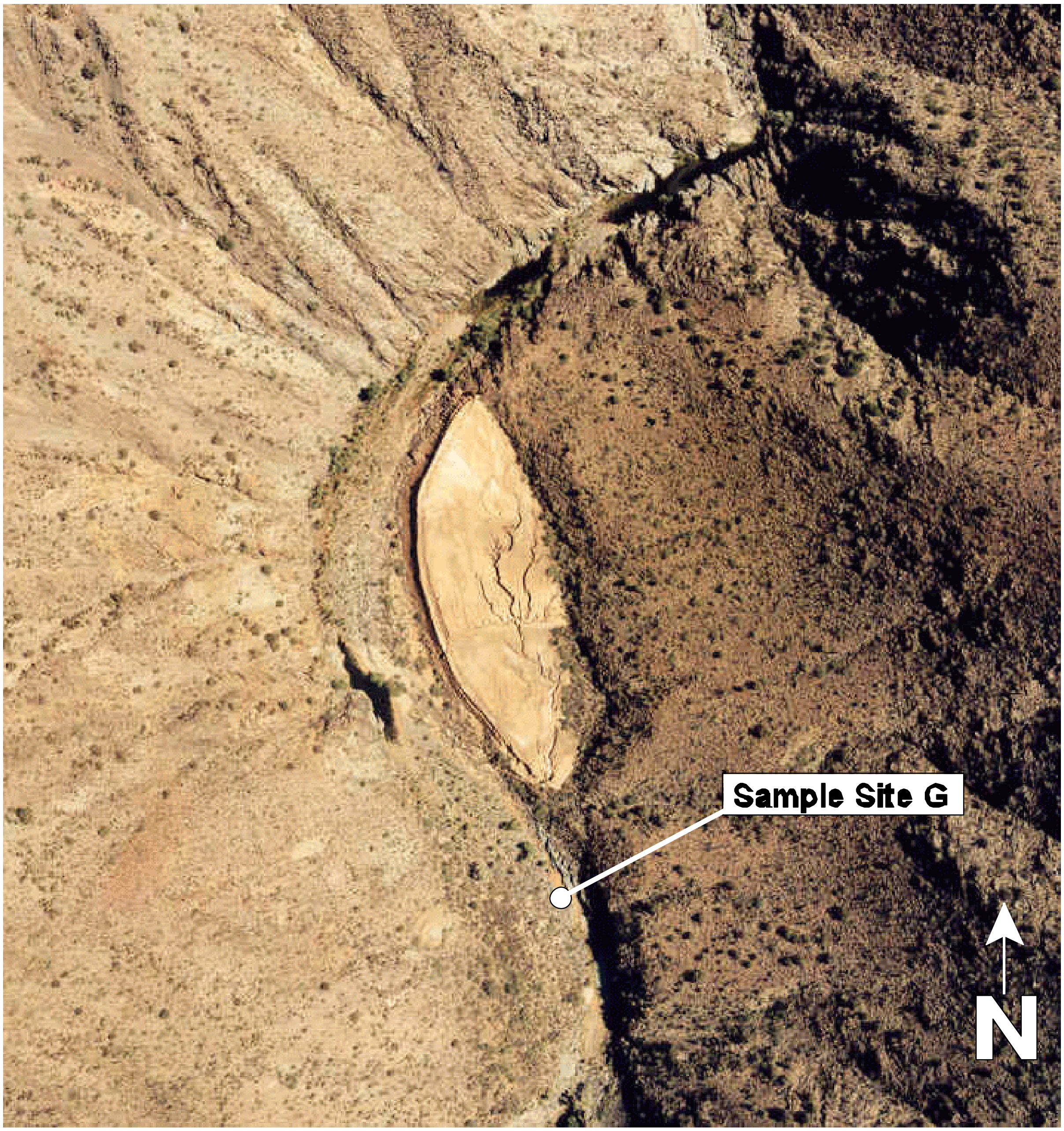

Figure 3-5 Lower Tailings Pile (photo courtesy of BLM, July 1999)

3.2.4 Discharge From Collapsed Adit

The adit discharge is located near the toe of the middle tailings pile (Figure 3-6). The flow from the adit is a constant 0.011 cfs (5 gpm) flow (approximately). After exiting the adit, the discharge flows about 30 feet before entering to Boulder Creek. The adit discharge was reported to have appeared in June, 1982 (ADHS, 1984). The discharge is slightly acidic, having a pH of 6. The water is clear, but the channel in which it flows is lined with an orange precipitate. The channel is also host to finger like colonies of iron-oxidizing bacteria (ADHS, 1984).

Figure 3-6 Adit discharge (December 2001)

3.3 Existing Loadings in Watershed

3.3.1 Adit Discharge

The existing loadings for each pollutant in the adit discharge are presented in Table 3-3. These loads are based on field measurements. The flow from the adit is a constant 5 gpm (approximately).

Table 3-4 Existing Loadings from Adit Discharge (g/day)

As	Cu	Zn
164.17	0.40	57.59

3.3.2 Nonpoint Source Loadings

3.3.2.1 Natural Background

Natural background concentrations of alkalinity, calcium, magnesium, and sulfate were calculated based on available historical STORET data for unimpaired segments of the upper Burro Creek watershed, including Boulder Creek (Figure 3-7). Because a statistical analysis of the data showed, the geometric mean of each chemical has a consistent concentration, the geometric mean was used to define natural background. The background concentrations of Butte and Copper Creek were also derived in the same way using available STORET data. When recent observation data were available, they were used instead of geometric mean of STORET values. (Tetra Tech, 2002)

The background concentrations of other metals such as arsenic, copper, manganese, and lead were derived from half of the detection limits of sampled metals from Site N (Figure 3-7). At site N, arsenic is <5ug/L, copper is <15ug/L, manganese is <20ug/L, and lead is <5ug/L. Therefore, half of each limits are arsenic: 2.5ug/L, copper: 7ug/L, manganese: 10ug/L, and lead: 2.5ug/L. The background concentrations for beryllium and iron were derived based on historical observed data and the best professional judgement from the site visits. For beryllium the concentration is 0.1 ug/L and for iron it is 3.5 ug/L. (Tetra Tech, 2002)

The existing loadings for each pollutant is listed by segment in Table 3-5 (Tetra Tech, 2002).

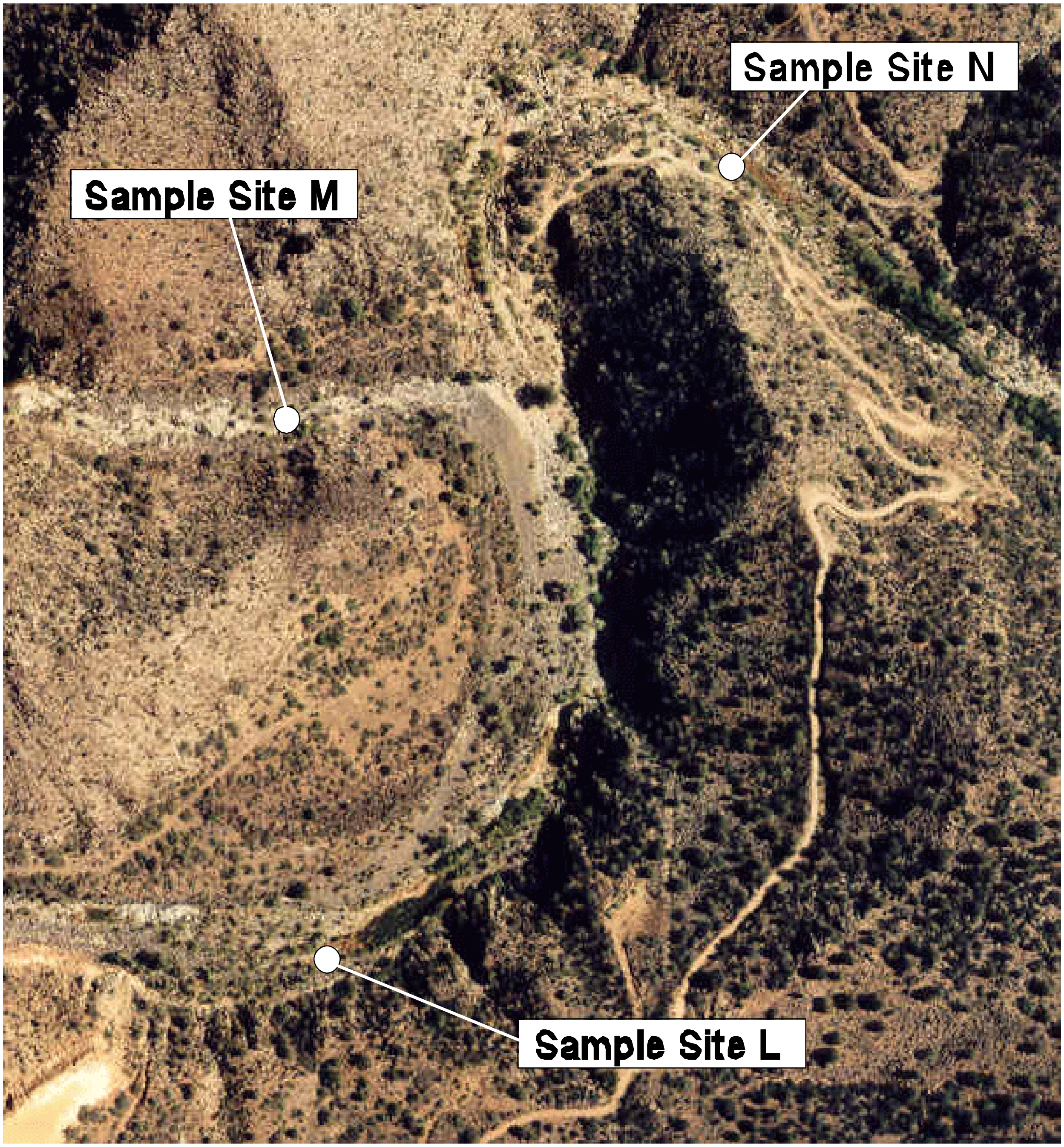

Figure 3-7 Sample sites above impacted reach (photo courtesy of BLM 1999).

Table 3-5 Existing Loadings from Natural Background (g/day)

	As	Cu	Zn
Upstream Boundary Conditions	7.9	23.7	31.6
Butte Creek Watershed	1.7	2.5	6.6
Zana Canyon Watershed (below Copper Ck)	2.5	7.4	9.9

3.3.2.2 Copper Creek Watershed

Phelps Dodge, Bagdad, Incorporated (PDBI) has the only permitted point source within the Boulder Creek watershed. PDBI holds an individual NPDES permit (AZ0022268) to discharge from three outlets to Copper Creek, a lower tributary to Boulder Creek. The NPDES permit contains limits for arsenic, cadmium, copper, lead, mercury, nickel, zinc, and pH. This permitted source does not regularly discharge into Copper Creek as a catchment basin has also been installed along the drainage to prevent runoff from entering Boulder Creek (Appendix D). Loading from the permitted source was represented implicitly within the background loading from the Copper Creek watershed (Tetra Tech, 2002). This is consistent with the findings of this draft TMDL. PDBI also has a general NPDES multi sector stormwater permit to discharge from a limited drainage between Butte and Copper Creeks. Modeling shows that no allocations for industrial stormwater discharges are necessary. During the course of this TMDL investigation, there were no discharges to Copper Creek.

Table 3-6 Existing Loading from Copper Creek Watershed (g/day)*

	As	Cu	Zn
Copper Creek Watershed	22.1	7.5	20.1

* These loads include contributions from the PD-Bagdad Mine.

3.3.2.3 Upper, Middle and Lower Tailings Piles

Sampling conducted in support of this TMDL clearly shows the impact of each tailings pile on Boulder Creek. The existing loadings for each metal are presented in Table 3-6.

Table 3-7 Existing Loadings from Tailings Piles (g/day)

	As	Cu	Zn
Upper Tailings Pile	43.2	61.4	605.8
Middle Tailings Pile	<1	<1	2.8
Lower Tailings Pile	<1	<1	217.1

4 ALLOCATION ANALYSIS

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \Sigma\text{WLAs} + \Sigma\text{LAs} + \text{MOS}$$

To develop TMDLs for Boulder Creek, the following approach was taken (Tetra Tech, 2002):

1. Collect and review recent and historic data
2. Select model(s)
3. Define TMDL endpoints
4. Simulate existing conditions
5. Assess source loading alternatives
6. Determine the TMDL and source allocations

Water quality data from fourteen ADEQ monitoring locations and EPA's STORET database were used to determine the extent, frequency, and conditions under which stream impairment occurs, as well as to define background water quality. Additional data from ADEQ, BLM, and USGS were also used to support water quality analysis (Tetra Tech, 2002).

4.1 Model Framework

The Mining Data Analysis System (MDAS) was applied to simulate watershed hydrological processes. MDAS is a system designed to support TMDL development for areas impacted by acid mine drainage (AMD). The system integrates the following:

- Graphical interface
- Data storage and management system
- Dynamic watershed model

The graphical interface supports basic geographic information systems (GIS) functions, including electronic geographic data importation and manipulation. Key data sets include stream networks, landuse, flow and water quality monitoring station locations, weather station locations, and permitted facility locations. The data storage and management system functions as database and supports storage of all data pertinent to TMDL development, including water quality observations, flow observations, permitted facilities, as well as stream and watershed characteristics used for modeling. The system also includes functions for inventorying the data sets.

The Dynamic Watershed Model, also referred to as the Hydrological Simulation Program C++ (HSPC), simulates nonpoint source flow and pollutant loading as well as in-stream flow and pollutant transport, and it is capable of representing time-variable point source contributions (Tetra Tech, 2002).

Because there was insufficient continuous in-stream water quality data to accurately calibrate the model for simulating source loadings, MDAS was not applied to simulate water quality conditions. In order to simulate the required stream flow and chemical processes of total and dissolved quantity of metals, an in-stream chemical speciation model was developed and applied to Boulder Creek.

The In-stream Chemical Speciation and Transport Model consists of two components. The first component is a physical transport model that assumes a steady-state flow condition. The second component is a chemistry module based on MINTEQA2 and MINEQL geochemical equilibrium speciation models in order to simulate in-stream chemical speciation. This model considers a variety of chemical processes including acid-base reactions, complexation, precipitation/dissolution, and sorption/desorption. The model calculates simultaneous solutions of nonlinear mass action expressions and linear mass balance relationships. These methods are frequently referred to as the "equilibrium constant method." These reactions are solved for set conditions within segments of a modeled stream in order to predict equilibrium systems in the water column. Each time the equilibrium calculation is performed, a new equilibrium status will be achieved, and the total concentration is redistributed into the three different components: dissolved, adsorbed, and precipitated. These components are then categorized as mobile and immobile. The dissolved component resides in water column and is subject to transport to the next segment. The amount that will be transported to the next segment among adsorbed and precipitated components will be based on the settling rates of each component. The remaining components in the segment can be thought of as mass that are adsorbed in the streambed, such as hydrous ferric oxide. These components are immobile and are not transported (Tetra Tech, 2002).

4.1.1 MDAS Hydrology Calibration

The hydrology calibration involved a comparison of model results to in-stream flow observations at selected locations and the subsequent adjustment of hydrologic parameters. Temporal comparisons (daily and monthly), and comparisons of high flows and low flows were developed to support calibration. The calibration involved adjustment of the infiltration, subsurface storage, evapotranspiration, surface runoff, and interception storage parameters (Tetra Tech, 2002).

After calibration, parameter values were validated for an independent, extended time period (between 1988 and 1998). Validation involved comparison of model results and flow observations without further adjustment of parameters (Tetra Tech, 2002).

4.1.2 In-stream Chemical Speciation Calibration

Boulder Creek was segmented into 1415 discrete cells. Each cell represents a 10 meter stream segment. Tributaries such as Wilder Creek, Butte Creek, Copper Creek and others flow into the specified cells of Boulder Creek. Each discrete cell required flow, and several chemistry parameters. The flow inputs, upper boundary, tributaries, and tailings pile flows were determined from MDAS. For chemistry inputs, the model required total concentrations of each metal (arsenic, zinc, manganese, copper, beryllium, and lead), alkalinity, atmospheric CO_2 pressure, other relatively conservative chemicals (calcium, magnesium, and sulfate), and the amount of iron which related to hydrous ferric oxide for adsorption (Tetra Tech, 2002).

The calibration was first conducted for a low flow condition (0.70 cfs). During the calibration, source loading characteristics and in-stream settling rates of metals were adjusted. Once this low flow calibration was complete, the same source loading characteristics and in-stream settling rates were transferred to a different low flow condition (0.80 cfs) for model validation purposes. After calibrating the model for low flow conditions, the high flow conditions (11.8 cfs) sampled by staff were simulated (Tetra Tech, 2002).

4.2 Critical Condition

The critical condition of Boulder Creek occurs during low flow (0.75 cfs). At, or below, this flow, the concentration of metals in the water column rises. There is also an increase in pH in the immediate vicinity of the sources (Tetra Tech, 2002). During low flow, waters from the adit seepage comprise a significant portion of the flow in Boulder Creek below the source. At higher flows, un-impacted waters provide dilution to the adit discharge and the model shows little to no negative water quality impacts.

4.3 Seasonal Variation

Stream flow in Boulder Creek responds dramatically to seasonal conditions. Flow ranges from spatially interrupted, independent pools in the summer to raging floods in response to large winter or summer monsoon storms. In this study seasonal variation was considered in the formulation of the modeling analysis. By using low and high flow conditions, seasonal hydrologic and source loading variability was inherently considered (Tetra Tech, 2002). The independent pools which are the remnants of the stream during low flow conditions are not sources of pollutants but act as a sink for those metals during the low flow periods. Choice of the critical condition and its application throughout the entire stream reach will ensure protection of Boulder Creek designated uses during all flow regimes.

4.4 Margin of Safety

An implicit MOS was included in TMDL development through application of a dynamic model for simulating daily flows over a wide range of hydrologic conditions, and through the use of conservative assumptions in model calibration and scenario development. In additional to this implicit margin of safety, a 5% explicit MOS was used to account for the difference between modeled and monitored data.

4.5 TMDL Endpoints for Water Quality Modeling

TMDL endpoints represent the in-stream water quality targets. Different TMDL endpoints are necessary for each parameter. Arizona's numeric water quality criteria for metals (Table 2-1) and an explicit margin of safety (MOS) were used to identify endpoints for TMDL modeling. To assure compliance of all applicable water quality standards, the most stringent water quality criteria among the specified use designations (e.g., chronic standards) were selected as TMDL endpoints, which will apply at all times (Tetra Tech, 2002).

4.5.1 Arsenic

The TMDL endpoint for total arsenic was selected as 47.5 μg/L (based on a 50 μg/L criteria for FBC minus a 5% MOS) (Tetra Tech, 2002).

Table 4-1 The Arsenic Endpoint

PARAMETER	MOST STRINGENT STANDARD	TMDL ENDPOINT WQS - 5% MOS
As	50 mg/L for FBC	50 - 2.5 = 47.5 mg/L

4.5.2 Copper and Zinc

The endpoints for dissolved copper and zinc were selected as the hardness-based chronic criteria for the A&Ww use designation minus a 5% MOS (Tetra Tech, 2002). The loading capacity for these two metals will vary throughout the stream because the surface water quality standards for these pollutants vary with hardness (not to exceed 400 mg/L). As noted in Section 4.1, the model calculates simultaneous solutions to mass action and mass balance equations. The model inputs calcium and magnesium values at each segment, and calculates the hardness. The hardness values for each day and reach segment were then averaged and compared to the appropriate calculated water quality standards at that location given the hardness values. As the model is run, it is determining the appropriate surface water quality standard at each segment with the appropriate hardness values. Reductions in loads are based on bringing the concentration levels into conformance with surface water quality standards throughout the listed reach. Based on the ADEQ sampling data collected for this TMDL, the in-stream hardness, for the entire reach from Wilder Creek to Burro Creek, averaged 225 mg/l as $CaCO_3$. This average hardness value is used below *to illustrate* the loading for each pollutant on Boulder Creek. [Note: These tables are *for illustration purposes only*. The final TMDL values are presented Table 4-6 are based on the dynamic modeling which accounts for ongoing changes throughout the stream].

Table 4-2 Copper and Zinc Endpoints (Illustration based on average stream hardness)

PARAMETER	MOST STRINGENT STANDARD (based on hardness = 225 mg/l)	TMDL ENDPOINT Chronic WQS - 5% MOS
Cu	A&W warm, chronic = 17.91 ug/l	17.91 - 0.90 = 17.01 ug/l
Zn	A&W warm, chronic = 232.9 ug/l	232.9 - 11.64 = 221.26 ug/l

4.5.3 Loading Capacity

Using the TMDL endpoints identified in the sections above and the critical flow of 0.75 cfs, the loading capacity per pollutant can be calculated. The TMDL endpoint and the loading capacities, per pollutant are shown in Table 4-3, after applying a unit conversion factor. As noted in section 4.5.2, the values are presented *for illustration purposes* based on an average in-stream hardness value of 225 mg/L. The actual load allocations, presented in section 4.7, are based on the modeling results which simulated varying hardness values and calculated appropriate SWQS based on those values.

Table 4-3 Loading Capacity per Pollutant (Illustration based on average stream hardness)

PARAMETER	TMDL ENDPOINT	LOADING CAPACITY
As	47.5 ug/l	87.03 g/day
Cu	17.01 ug/l	31.19 g/day
Zn	221.26 ug/l	405.75 g/day

4.6 TMDL Calculation and Allocations

As discussed in section 3.1, ADEQ proposes to remove all pollutants from that portion of Boulder Creek below Copper Creek as the data collected in support of this TMDL shows insufficient signs to warrant those pollutants remaining on the 303(d) List. The following allocations are for arsenic, copper, and zinc from Wilder Creek to Copper Creek.

4.6.1 Wasteload Allocations

Waste load allocations (WLAs) for the collapsed adit were made based on the model results. The flow from the adit was represented conceptually as a constant 5 gpm. The existing loadings for each metal are presented in Table 3-4. Table 4-4 shows the WLAs. The WLAs are presented as daily loads, in terms of grams per day (Tetra Tech, 2002). The allocation is based on the model results which looked at reductions of all the pollutants simultaneously in order to meet the appropriate surface water quality standards. To conduct strict arithmetic exercise, on a per-pollutant basis, to try and meet surface water quality standards may result in slightly different reduction values. It may also be noted that remediation strategies of the sources (i.e., tailings piles) will likely address all pollutants simultaneously rather than on a pollutant specific basis. Applying the reduction value of the pollutant requiring the greatest reduction to all pollutants will assure that all parameters will meet the appropriate water quality standards.

Table 4-4 WLAs (g/day)-Adit Discharge

As	Cu	Zn	Reduction (%) from Existing Loadings
24.6	0.1	8.6	85

* No allocation necessary based on modeling results.

4.6.2 Load Allocations

The load allocations (LA) for each metal are presented in Table 4-5. Load allocations apply to flows at, or below, the critical condition of 0.75 cfs. At higher flows, un-impacted waters provide dilution and there is little to no negative water quality impacts. Since concentration data from precipitation-induced washoff from the tailings piles are not available, these values were adjusted based on source loading characteristic variables in the model. The load allocations are presented as daily loads, in terms of grams per day. ADEQ has placed the tailings piles in the LA portion of the TMDL. If, upon further investigation, it turns out the piles will require point source permitting, the allocations would shift to the WLA column, but the overall TMDL numbers would not change.

Table 4-5 Load Allocations (g/day) for Tailings Piles

	As	Cu	Zn	Average Reduction (%) from Existing Loadings
Upper Tailings Pile	9.5	13.5	133.3	78
Middle Tailings Pile	*	*	1.7	40
Lower Tailings Pile	*	*	97.7	55

* No allocation necessary

4.6.3 Boulder Creek TMDL

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL contains a 5% explicit MOS (discussed in section 4.4) to account for differences between modeled and monitored data.

Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = 3\text{WLAs} + 3\text{LAs} + \text{MOS}$$

The TMDLs for Boulder Creek identify the total amount of pollutant that can be assimilated by the receiving system while still achieving water quality standards. These TMDLs are for copper and zinc from Wilder Creek to Copper Creek and for arsenic from Wilder Creek to the unnamed tributary of Boulder, just above Zana Canyon.

Table 4-6 Boulder Creek TMDLs

	Wilder Creek to Copper Creek			**Copper Creek to Unnamed Tributary to Boulder, above Zana Canyon**
	As (g/day)	**Cu (g/day)**	**Zn (g/day)**	**As (g/day)**
LA	19.1	39.7	270.9	22.1
WLA	24.6	0.1	8.6	0
MOS	2.2	2.0	14.0	1.1
TMDL	45.9	41.8	293.5	23.2

5 IMPLEMENTATION

EPA recognizes that water quality problems that result in TMDLs are often generated over multiple generations and may require as long to correct (US EPA, 1999). Implementation plans are highly dependent upon the volunteer approach of land managers in implementing projects and BMPs. Cooperation of State and Federal agencies and private landowners will be paramount in the implementation of this TMDL. ADEQ has grant funding available, as do other agencies, to help implement watershed restoration plans. ADEQ's Watershed Management Program is able to perform public outreach and to assist landowners in securing funding.

In September 1999, AMEC Earth & Environmental[2], in cooperation with BLM, conducted a site characterization of the mine tailings and adit seep (AGRA, 2000). BLM used the data obtained from the site characterization to prepare an Engineering Evaluation/Cost Analysis (EE/CA) of the site (BLM, 2000). Due to the proximity of the middle tailings pile to the upper tailings pile, BLM included the middle tailings pile in their initial remediation plans. The lower tailings pile was not considered because of its accessibility issues. The EE/CA provided an alternatives analysis for remedial actions at the site. The recommendation was to consolidate the upper and middle tailings

[2]Formerly AGRA Earth & Environmental, Inc.

piles. The tailings would be moved out of the 100 year flood plain and runon/runoff controls would be placed on the capped surface (BLM, 2000). An oxidation pond would be constructed to address the adit discharge.

During a meeting in February 2001, representatives from EPA's Emergency Response Office clarified their intent to assist BLM with the project. EPA was willing to provide financial assistance, manage the project under CERCLA, if necessary, and take enforcement action against the private owners of the middle tailings pile. In March 2001, AMEC submitted an Engineering Analysis and Design to BLM. This report outlined the engineering analysis, proposed design layout of the consolidated tailings piles, and preliminary construction plans (AMEC, 2001a). During a meeting in May 2001, general design/concept data gaps were identified. AMEC agreed to conduct some follow-up work to address the data gaps.

AMEC submitted an updated proposal in September 2001. In the updated proposal, the tailings piles would be left in place, regraded, and capped (AMEC, 2001b). Concerns about the strength characteristics and total volume of the combined tailings prompted the change. Also at this time, KFX submitted to EPA a mining and remediation proposal for the middle tailings pile. In this plan, KFX would excavate the tailings, process them, redeposit the materials, and cap them. The processing would to be done in a 500 ton-per-day closed loop system. EPA addressed their proposal and stipulated that EPA would monitor the process under CERCLA. EPA also stipulated that KFX would have to enter a three party agreement with EPA and BLM, post adequate financial surety, and complete the process in 15 months. BLM's project was put on hold until the situation with KFX could be resolved. KFX has since rescinded the proposal to reprocess the tailings piles and is discussing reclamation possibilities with EPA (EPA, 2002). There is no estimated time frame for any remedial action at the middle tailings pile. BLM is moving forward on their plans to remediate the upper tailing pile (BLM, 2002). The cultural survey is supposed to be started late spring or early summer 2002. Actual construction is not expected to start until spring 2003.

ADEQ is assisting the Arizona State Land Department in applying for a Clean Water Act Section 319 grant to develop and start a reclamation project for the lower tailings pile. Due to site accessibility issues and cost limitations, the best implementation strategy will likely be to regrade and cap the tailings pile. Runon/runoff controls would have to be constructed to prevent degradation of the capping material and subsequent erosion of the underlying tailings piles. Institutional controls, such as fencing or barricades, would need to be put in place to prevent individuals from destroying the capping materials.

One alternative for the adit discharge is an onsite reclamation pond. This would more than likely involve an open pit lined with crushed limestone or other material to induce precipitation of metals and increase pH. The pond would have to undergo periodic maintenance to move precipitated metals.

6 MONITORING

ADEQ intends to conduct follow-up monitoring five years after the approval of this TMDL. At the very least, this will help assess the effectiveness of BLM's efforts to remediate the upper tailings pile. If the middle and lower tailings piles and the adit seepage are eventually addressed in a remediation/reclamation plan, follow-up monitoring will also assess the effectiveness of those plans.

7 PUBLIC PARTICIPATION

Public participation was encouraged and received throughout the development of this TMDL. A total of six meetings were held during this process. Involved parties include EPA, BLM, US Army Corps of Engineers, ADEQ, Arizona State Land Department, Arizona Game and Fish Department, KFX, Phelps Dodge, and representatives from contractors involved with all levels of the projects mentioned previously. The draft TMDL report was made available for a 30-day public comment period starting July 12, 2002. Public notice of the availability of the draft document was made through a posting in a newspaper of general circulation *The Daily Courier*; by email notifications; phone calls; and webpage postings. The draft Boulder Creek TMDL was presented in a public meeting in Bagdad, AZ, on July 23, 2002. Comments received during the public notice period were addresses in a public notice, in the A.A. R. which was carried on October 25, 2002. After the 45-day public comment period for the A.A.R. notice was completed it was decided that the loads and allocations would be re-modeled based on the new water quality standards which were approved by EPA November 13, 2002. This report presents the findings of the re-modeled loads and allocations. There will be a 30-day public comment period for the re-drafted report.

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APPENDIX A
TMDL PROGRAM SAMPLING DATA

Site ID: A	Topo Quad:	Grayback Mtn	Lat:	34 36 46.322	Long:	113 14 56.695
Sample Date	30 November 2000	4 January 2001	28 February 2001	28 March 2001	24 April 2001	23 May 2001
TDS mg/l	438	466	67	220	307	330
TSS mg/l	<1	<1	146	1	<1	<1
Hardness mg/l	255	320	60	168	126	217
As(T) mg/l	16	15	19	25	17	14
As(D) mg/l	17	13	7	28	15	13
Be(T) mg/l	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	<15	<15	36	<15	<15	<15
Cu(D) mg/l	<15	<15	<15	<15	<15	<15
Pb(T) mg/l	<5	<5	34	<5	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	40	30	510	50	<20	<20
Mn(D) mg/l	40	20	<20	50	<20	<20
Zn(T) mg/l	<20	<60	270	20	<20	Error
Zn(D) mg/l	<20	<20	30	<20	<20	<20
Sulfate mg/l			13.9	8.6	55	68
A&Ww						
WQS(D)						
As	20	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3
Cu	20	24	6	14	11	17
Mn	10000	10000	10000	10000	10000	10000
Pb	7	9	1.4	4.4	3.2	6
Zn	259	314	76	76	143	226
Date	30-Nov-00	04-Jan-01	28-Feb-01	28-Mar-01	24-Apr-01	23-May-01
Time	1115	1000	945	915	815	800
Q (cfs)	0.696	0.79		5.667	2.533	0.483
Q(gpm)	312	355		2544	1137	217
MGD	0.450	0.511		3.663	1.637	0.312
pH	7.92		7.35	7.6	7.42	7.12
Tw(ºC)	10.33	6.14	7.69	14.54	15.65	20.87
Tw(ºF)	50.59	43.05	45.84	58.17	60.17	69.57
SpecCon	649.2	795.7	85.7	472.1	589.3	638
DO mg/l	7.69		10.54	8.6	8.39	3.94
DO%	105.1		98.8	91.1	100.02	48

ORP	366	462	492	363	326	270

Site ID: B	Topo Quad:	Bagdad	Lat:	34 36 26.369	Long:	113 13 54.452	
Sample Date	30 November 2000	4 January 2001	31 January 2001	28 February 2001	28 March 2001	24 April 2001	23 May 2001
TDS mg/l	331	368	128	81	183	296	484
TSS mg/l	<1	<1	<1	32	1	<1	<1
Hardness mg/l	187	242	60	60	73	115	155
As(T) mg/l	44	**52**	18	11	39	48	29
As(D) mg/l	42	50	19	6	36	45	27
Be(T) mg/l	<2	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	<15	<15	<15	17	<15	<15	<15
Cu(D) mg/l	<15	<15	<15	<15	<15	<15	<15
Pb(T) mg/l	<5	<5	<5	6	<5	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	50	30	30	150	30	<20	20
Mn(D) mg/l	40	30	20	20	20	<20	<20
Zn(T) mg/l	40	<60	60	90	30	<20	Error
Zn(D) mg/l	20	20	50	30	<20	<20	<20
Sulfate mg/l			20.1	12.2	34.9	54	138
A&Ww							
WQS(D)							
As	50	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Cu	15	19	6	6	7	10	13
Mn	10000	10000	10000	10000	10000	10000	10000
Pb	5	6.5	1.4	1.4	1.8	3	4
Zn	199	248	76	76	90	132	170
Date	30-Nov-00	04-Jan-01	31-Jan-01	28-Feb-01	28-Mar-01	24-Apr-01	23-May-01
Time	1645	1430	1230	1530	1300	1130	1400
Q (cfs)	0.956						
pH	8.07		7.69	6.64	8.16	8.31	7.87
Tw(ºC)	11.94	9.12	6.06	7.22	19.92	21.2	31.6
Tw(ºF)	53.49	48.42	42.91	45.00	67.86	70.16	88.88
SpecCon	495.9	659.6	200.1	92	339.6	588.4	847.3
DO mg/l	9.93		11.65	10.73	8.51	8.43	10.42
DO%	101.5		102.5	98.6	101.5	112.7	157

ORP	357	453	394	480	357	258	236

Site ID: E	Topo Quad:	Bagdad	Lat:	34 36 50.847	Long:	113 13 11.501
Sample Date	30 November 2000	4 January 2001	31 January 2001	28 February 2001	28 March 2001	24 April 2001
TDS mg/l	273	328	118	100	139	268
TSS mg/l	2	<1	<1	36	<1	<1
Hardness mg/l	153	118	57	60	106	100
As(T) mg/l	**58**	**72**	16	11	47	**76**
As(D) mg/l	52	68	16	<5	51	73
Be(T) mg/l	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	<15	<15	<15	<15	<15	<15
Cu(D) mg/l	<15	<15	<15	<15	<15	<15
Pb(T) mg/l	<5	<5	<5	<5	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	90	60	40	160	90	50
Mn(D) mg/l	80	60	30	20	70	50
Zn(T) mg/l	100	70	70	70	60	50
Zn(D) mg/l	70	50	60	<20	40	50
Sulfate mg/l			15.2	11.3	17.7	31.2
A&Ww						
WQS(D)						
As	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3
Cu	13	10	6	6	9	9
Mn	10000	10000	10000	10000	10000	10000
Pb	4	3	1.4	1.4	2.7	2.5
Zn	168	135	73	76	123	117
Date	30-Nov-00	04-Jan-01	31-Jan-01	28-Feb-01	28-Mar-01	24-Apr-01
Time	1530	1345	1145	1345	1145	1045
Q (cfs)	1.192					
pH	7.92		7.16	7.5	7.97	8.16
Tw(ºC)	11.22	10	5.36	6.73	19.3	20.33
Tw(ºF)	52.20	50.00	41.65	44.11	66.74	68.59
SpecCon	415.1	586	180.6	92.3	293.9	511.8
DO mg/l			11.45	10.92	8.03	9.3
DO%			99.1	99.5	95	122.2
ORP	366	303	404	438	310	275

Site ID: G	Topo Quad:	Bozarth Mesa	Lat:	34 37 32.971	Long:	113 12 57.431	
Sample Date	30 November 2000	3 January 2001	30 January 2001	27 February 2001	27 March 2001	25 April 2001	22 May 2001
TDS mg/l	304	326	122	58	148	265	338
TSS mg/l	<1	<1	<1	9	<1	<1	<1
Hardness mg/l	175	211	55	52	103	100	106
As(T) mg/l	**57**	**63**	11	<5	31	**74**	**66**
As(D) mg/l	50	60	12	<5	32	72	66
Be(T) mg/l	<2	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	<15	<15	<15	<15	16	<15	<15
Cu(D) mg/l	<15	<15	<15	<15	<15	<15	<15
Pb(T) mg/l	<5	<5	<5	<5	<5	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	260	260	60	50	110	100	70
Mn(D) mg/l	260	210	40	<20	100	90	50
Zn(T) mg/l	240	190	80	30	110	140	Error
Zn(D) mg/l	180	140	60	<20	60	90	190
Sulfate mg/l			16.2	12.8	15	28.4	91
A&Ww							
WQS (D)							
As	50	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Cu	14	17	5	5	9	9	9
Mn	10000	10000	10000	10000	10000	10000	10000
Pb	4.6	5.6	1.3	1.2	2.6	2.5	2.7
Zn	188	221	71	67	120	117	123
Date	30-Nov-00	03-Jan-01	30-Jan-01	27-Feb-01	27-Mar-01	25-Apr-01	22-May-01
Time	1615	1030	0930	1100	1045	945	1145
Q (cfs)	0.983	0.960	15.680		3.751	1.154	0.158
Q(gpm)	441	431	7038		1684	518	71
MGD	0.635	0.620	10.134		2.424	0.746	0.102
pH	7.55	7.04	6.95	7.35	7.77	8.35	7.51
Tw(ºC)		5.54	4.93	7.17	16.01	18.53	24.91
Tw(ºF)		41.97	40.87	44.91	60.82	65.35	76.84
SpecCon	455.7	569.6	167.3	95.1	272.1	507.4	635.9
DO mg/l			11.13	10.61	7.68	8.17	5.86
DO%			89.9	98	86.6	103.7	80.1
ORP	318	699	371	513	385	227	268

Site ID: H		Topo Quad:	Bozarth Mesa	Lat:	34 37 57.904	Long:	113 12 42.161					
Sample Date	29-Nov-00	03-Jan-01	30-Jan-01	27-Feb-01	27-Mar-01	25-Apr-01	22-May-01	26-Jun-01	18-Jul-01	15-Aug-01	28-Aug-01	2 November 2001	31 December 2001
TDS mg/l	305	336	116	71	145	233	432	1500	1520	986	1740	1670	444
TSS mg/l	<1	<1	<1	10	<1	<1	2	14	<1	13	2	2	<1
Hardness mg/l	179	216	55	52	106	100	163	1010	1090	320	961	1084	276
As(T) mg/l	**55**	**67**	9	<5	28	**79**	39	**188**	**223**	**256**	**250**	**287**	**73**
As(D) mg/l	45	56	9	<5	29	75	25	116	138	70	136	96	46
Be(T) mg/l	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	16	<15	<15	<15	<15	<15	<15	<15	<15	30	<10	<10	150
Cu(D) mg/l	<15	<15	<15	<15	<15	<15	<15	<15	<15	20	<10	<10	**80**
Pb(T) mg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<50	<5	<10
Pb(D) mg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<20	<5	<5
Mn(T) mg/l	310	180	50	40	120	230	1160	2580	2120	**10700**	**11800**	6870	700
Mn(D) mg/l	290	280	40	<20	120	220	1110	2370	2280	9940	12000	6540	620
Zn(T) mg/l	220	220	70	30	110	110	Error	260	200	6820	2400	780	1790
Zn(D) mg/l	150	140	60	<20	60	50	90	170	180	**4460**	**2340**	**700**	**1370**
Sulfate mg/l			14.6	14	14.9	23.9	154	960	1040	242	965	965	74.2
A&Ww													
WQS (D)													
As	50	50	50	50	50	50	50	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Cu	15	17	5	5	9	9	14	29	29	24	29	29	21
Mn	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Pb	4.7	5.8	1.3	1.2	2.7	2.5	4.3	11	11	8.7	11	11	7.5
Zn	192	225	71	67	123	117	177	379	379	314	379	379	272
Date	29-Nov-00	03-Jan-01	30-Jan-01	27-Feb-01	27-Mar-01	25-Apr-01	22-May-01	26-Jun-01	18-Jul-01	15-Aug-01	28-Aug-01	02-Nov-01	31-Dec-01
Time	1715	1130	1030	1230	1145	1030	1045	930	820	1600	1130	1030	1125
Q (cfs)	0.773	0.847	11.601		3.357	1.125	0.113	0.013	0.011	0.134	0.012	0.012	
Q(gpm)	347	380	5207		1507	505	51	5.83	4.94	60.00	5.23	5.17	
MGD	0.500	0.547	7.498		2.170	0.727	0.073	0.008	0.007	0.087	0.008	0.008	
pH	7.78	8.26?	7.23	7.55	7.84	8.26	7.4	7.57	7.77	7.76		7.35	8.29
Tw(ºC)		6.54	4.75	7.62	16.43	18.8	23.95	23.78	24.13	29.77	28.21	15.05	8.7
Tw(ºF)		43.77	40.55	45.72	61.57	65.84	75.11	74.80	75.43	85.59	82.78	59.09	47.66
SpecCon	468.6	555	165.9	93.8	281.1	518.3	800.2	2259	2379	1175	1794	2111	765.7
DO mg/l			11.5	10.42	7.75	8.59	8.14	6.1	7.15	7.02	6.68	7.81	
DO%			92.5	97.1	88	114.2	107.6	76	93.1	92.9	95.9	85.3	
ORP	313	657	359	438	332	265	255	250	325		425		

Site ID: J	Topo Quad:	Bozarth Mesa	Lat:	34 38 04.369	Long:	113 12 38.542
Sample Date	29 November 2000	3 January 2001	30 January 2001	27 February 2001	27 March 2001	22 May 2001
TDS mg/l	271	309	129	84	146	261
TSS mg/l	<1	<1	<1	7	<1	1
Hardness mg/l	168	200	55	52	103	90
As(T) mg/l	21	18	5	<5	9	34
As(D) mg/l	13	15	<5	<5	9	32
Be(T) mg/l	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	18	<15	<15	<15	<15	<15
Cu(D) mg/l	<15	<15	<15	<15	<15	<15
Pb(T) mg/l	<5	<5	<5	17	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	120	60	30	70	50	40
Mn(D) mg/l	100	50	20	<20	50	30
Zn(T) mg/l	210	160	60	30	60	Error
Zn(D) mg/l	150	120	50	<20	40	20
Sulfate mg/l			12.5	15.8	10.4	24.8
A&Ww						
WQS (D)						
As	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3
Cu	14	16	5	5	9	8
Mn	10000	10000	10000	10000	10000	10000
Pb	4.4	5.3	1.3	1.2	2.6	2.2
Zn	182	211	71	67	120	107
Date	29-Nov-00	03-Jan-01	30-Jan-01	27-Feb-01	27-Mar-01	22-May-01
Time	1800	1315	1145	1315	1300	1315
pH	7.82	7.81		7.75	7.17	7.83
Tw(ºC)		8.01		8.17	16.7	24.9
Tw(ºF)		46.42		46.71	62.06	76.82
SpecCon	445.2	530.4		90.2	275.6	567.9
DO mg/l				10.03	7.58	7.49
DO%				95	86.4	100.9
ORP	219	647		390	336	245

Site ID: JJ	Topo Quad:	Bozarth Mesa	Lat:	34 38 17.7	Long:	113 12 40.6
Sample Date	25 April 2001	22 May 2001	15 August 2001	31 December 2001		
TDS mg/l	237	319	2600	410		
TSS mg/l	<1	<1	11	7		
Hardness mg/l	95	103	1064	231		
As(T) mg/l	14	22	**58**	**15**		
As(D) mg/l	9	22	<25	11		
Be(T) mg/l	<2	<2	12	<2		
Be(D) mg/l	<2	<2	13	<2		
Cu(T) mg/l	<15	19	15200	140		
Cu(D) mg/l	<15	<15	**14400**	**80**		
Pb(T) mg/l	<5	<5	<5	<5		
Pb(D) mg/l	<5	<5	<5	<5		
Mn(T) mg/l	30	30	**23400**	**310**		
Mn(D) mg/l	20	<20	21600	290		
Zn(T) mg/l	100	Error	**129000**	1170		
Zn(D) mg/l	70	60	**115000**	**900**		
Sulfate mg/l	11.7	39	1780	46		
A&Ww						
WQS (D)						
As	50	50	50	50		
Be	5.3	5.3	5.3	5.3		
Cu	9	9	29	18		
Mn	10000	10000	10000	10000		
Pb	2.4	2.6	11	6.2		
Zn	112	120	379	238		
Date	25-Apr-01	22-May-01	15-Aug-01	31-Dec-01		
Time	1200	1430	1519	1050		
pH	7.9	8.02	3.71	8.07		
Tw(ºC)	21.55	29.4	28.98	8.58		
Tw(ºF)	70.79	84.92	84.16	47.44		
SpecCon	488	609	3046	710.8		
DO mg/l	8.59	7.19	5.48			
DO%	115.7	105.3	72			
ORP	219	241				

Site ID: L	Topo Quad:	Bozarth Mesa	Lat:	34 38 18.030	Long:	113 12 20.258
Sample Date	26 October 2000	29 November 2000	3 January 2001	30 January 2001		
TDS mg/l		273	302	100		
TSS mg/l		ND	<1	<1		
Hardness mg/l	230	174	191	55		
As(T) mg/l	11	9	10	<5		
As(D) mg/l	ND	9	9	<5		
Be(T) mg/l	ND	<2	<2	<2		
Be(D) mg/l	ND	<2	<2	<2		
Cu(T) mg/l	ND	<15	<15	<15		
Cu(D) mg/l	ND	<15	<15	**<15**		
Pb(T) mg/l	ND	<5	<5	<5		
Pb(D) mg/l	ND	<5	<5	<5		
Mn(T) mg/l	ND	40	30	<20		
Mn(D) mg/l	ND	30	20	<20		
Zn(T) mg/l	ND	<20	<60	<20		
Zn(D) mg/l	ND	<20	<20	<20		
Sulfate mg/l				10.8		
A&Ww						
WQS (D)						
As	50	50	50	50		
Be	5.3	5.3	5.3	5.3		
Cu	18	14	16	5		
Mn	10000	10000	10000	10000		
Pb	6.2	4.6	5.1	1.3		
Zn	237	187	203	71		
Date	26-Oct-00	29-Nov-00	03-Jan-01	30-Jan-01		
Time	1630	1230	1400	1315		
Q (cfs)		0.754				
pH		7.59		7.16		
Tw(ºC)		9.24		6.14		
Tw(ºF)		48.63		43.05		
Ta						
SpecCon		451		156.9		
DO mg/l		8.68		10.6		
DO%		84		88.5		
ORP		349		322		

Site ID: M	Topo Quad:	Bozarth Mesa	Lat:	34 38 25.976	Long:	113 12 18.245	
Sample Date	29 November 2000	3 January 2001	30 January 2001	27 March 2001	25 April 2001	22 May 2001	31 December 2001
TDS mg/l	325	323	207	225	272	285	356
TSS mg/l	<1	<1	<1	1	<1	<1	<1
Hardness mg/l	199	205	114	169	95	83	246
As(T) mg/l	8	11	12	10	9	10	9
As(D) mg/l	9	10	14	13	7	9	11
Be(T) mg/l	<2	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	<15	<15	<15	<15	<15	<15	<20
Cu(D) mg/l	<15	<15	<15	<15	<15	<15	<10
Pb(T) mg/l	<5	<5	<5	<5	<5	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	<20	<20	<20	<20	<20	<20	<20
Mn(D) mg/l	<20	<20	<20	<20	<20	<20	<20
Zn(T) mg/l	<20	<60	<20	60	<20	Error	<20
Zn(D) mg/l	<20	<20	<20	<2	<20	<20	<20
Sulfate mg/l			**6.9**	**8**	**6.9**	**<5**	**12.3**
A&Ww							
WQS (D)							
As	50	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Cu	16	17	10	14	9	8	19
Mn	10000	10000	10000	10000	10000	10000	10000
Pb	5.3	5.5	2.9	4.4	2.4	2.1	6.6
Zn	210	215	131	183	112	100	251
Date	29-Nov-00	03-Jan-01	30-Jan-01	27-Mar-01	25-Apr-01	22-May-01	31-Dec-01
Time	1130	1515	1430	1430	1330	1545	911
Q (cfs)	0.862	1.33	2.3	0.873	0.279	0.094	0.371
Q (gpm)	387	597	1032	392	125	42	166.67
MGD	0.557	0.860	1.487	0.564	0.180	0.061	0.240
pH	7.87		7.8	8.02	8.6	8.21	7.79
Tw(ºC)	10.38	7.72	6.76	16.88	20.67	28.4	8.52
Tw(ºF)	50.68	45.90	44.17	62.38	69.21	83.12	47.34
SpecCon	530.4	544.3	363.6	441.2	533	568.7	606.5
DO mg/l	10.23		11.03	9.11	10.67	8.5	
DO%	101		93.1	104.3	140.8	122.2	
ORP	331	543	291	293	189	248	

Site ID: N	Topo Quad:	Bozarth Mesa	Lat:	34 35 26.704	Long:	113 12 06.502		
Sample Date	29 November 2000	3 January 2001	30 January 2001	27 February 2001	27 March 2001	25 April 2001	22 May 2001	31 December 2001
TDS mg/l	147	207	88	66	92	155	288	394
TSS mg/l	ND	<1	<1	17	2	<1	<1	3
Hardness mg/l	75	123	37	47	67	75	128	172
As(T) mg/l	<5	<5	<5	<5	<5	<5	<5	<5
As(D) mg/l	<5	<5	<5	<5	<5	<5	<5	<5
Be(T) mg/l	<2	<2	<2	<2	<2	<2	<2	<2
Be(D) mg/l	<2	<2	<2	<2	<2	<2	<2	<2
Cu(T) mg/l	<15	<15	<15	<15	<15	<15	<15	<20
Cu(D) mg/l	<15	<15	<15	<15	<15	<15	<15	<10
Pb(T) mg/l	<5	<5	<5	<5	<5	<5	<5	<5
Pb(D) mg/l	<5	<5	<5	<5	<5	<5	<5	<5
Mn(T) mg/l	30	<20	<20	50	30	<20	70	<20
Mn(D) mg/l	30	<20	<20	<20	30	<20	60	<20
Zn(T) mg/l	<20	<60	<20	30	20	<20	Error	Possible error 140
Zn(D) mg/l	<20	<20	<20	<20	<20	<20	<20	<20
Sulfate mg/l			13.4	10.6	9.3	6.9	<5	47.4
A&Ww								
WQS (D)								
As	50	50	50	50	50	50	50	50
Be	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Cu	7	11	4	5	6	7	11	14
Mn	10000	10000	10000	100000	10000	10000	10000	10000
Pb	1.8	3.2	0.84	1.1	1.6	1.8	3.3	4.5
Zn	92	140	57	62	84	93	144	182
Date	29-Nov-00	03-Jan-01	30-Jan-01	27-Feb-01	27-Mar-01	25-Apr-01	22-May-01	31-Dec-01
Time	1015	1430	1345	1515	1515	1415	1600	935
Q (cfs)	0.32	0.217	9.317		1.869	1	0.01	0.129
Q (gpm)	144	97	4182		839	449	4	58
MGD	0.207	0.140	6.022		1.208	0.646	0.006	0.083
pH	6.75	6.67	7.15	7.57	7.56	7.56	7.4	7.89
Tw(ºC)	8.75	8.92	5.26	7.71	17.6	25.42	32.37	8.13
Tw(ºF)	47.75	48.06	41.47	45.88	63.68	77.76	90.27	46.63
SpecCon	217.2	342.6	108.8	62.2	185.3	338.1	545.7	684.8
DO mg/l	9.16		10.7	10.12	7.54	8.39	6.93	
DO%	87.4		87	94.7	87.8	121.6	105.4	
ORP	308	685	333	470	311	248	272	

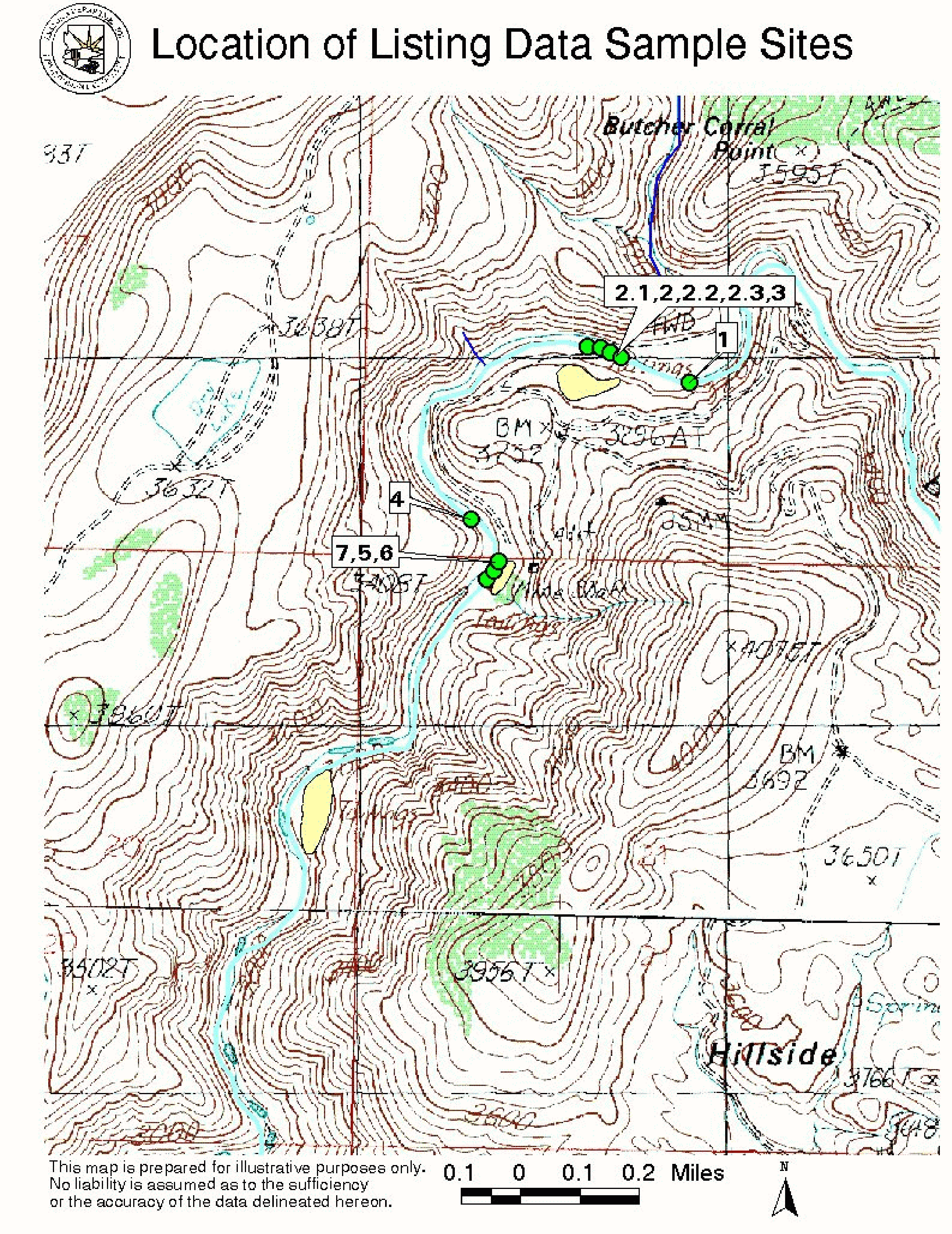
APPENDIX B
SUMMARY OF LISTING DATA

SUMMARY OF LISTING DATA-October 22, 1992

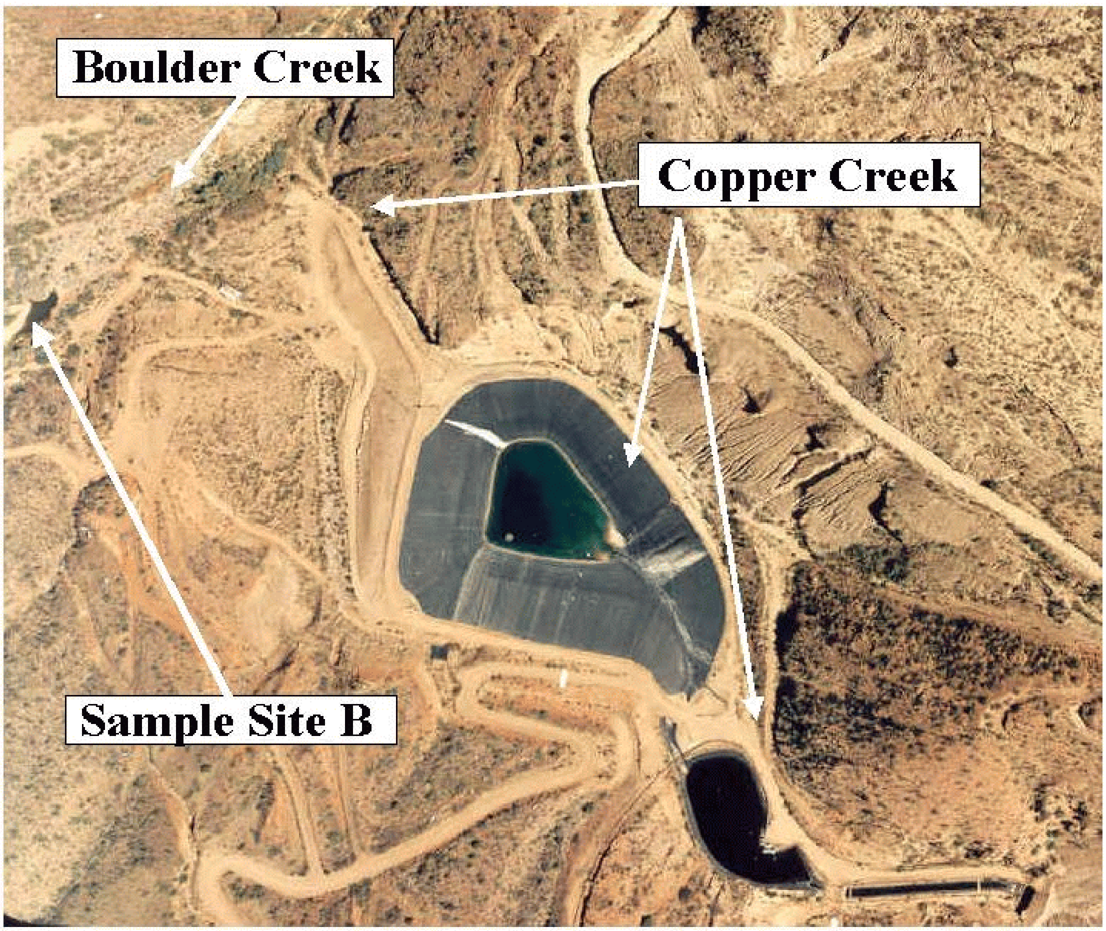
SITE ID	Be, T Fg/L		Zn, T Fg/L		Zn, D[1] Fg/L		As, T Fg/L		As, D Fg/L		Pb, T Fg/L		Mn, T Fg/L		Cu, D[1] Fg/L	
	value	std	value	std	value	std	value	std	value	std	value	std	value	std	value	std
#2.1	0.8	0.21 FC	17300	10000 AgI	1700	(591)[3] 527									155	(591)[3] 95
#2.2			14300	10000 AgI	13100	(591)[3] 527										
#2	0.9	0.21 FC			7570	(591)[3] 527	19	3.1 FC								
#2.3					1530	(591)[3] 527	10	3.1 FC								
#3					1290	(482)[3] 444	12	3.1 FC								
#4							13	3.1 FC								
#5[4]	11	0.21 FC			1600	(1300)[3] 1030	15000	3.1 FC	5450	360 AWw	130	100 AgL	22000	10000 AgI		
#6	1.9	0.21 FC					500	3.1 FC					13100	10000 AgI		
#7	1.1	0.21 FC					150	3.1 FC								

1 Standard based on hardness
2 FBC standard is currently 50 Fg/L
3 Hardness expressed in mg/L $CaCO_3$. Standards for Zn,D and Cu,D for sites #2.1, #2.2, and #2.3 are calculated using the hardness value for site #2
4 Site #5 corresponds to ADEQ TMDL sampling site I. This is the adit discharge, not waters of Boulder Creek

Location of Listing Data Sample Sites



APPENDIX C
COPPER CREEK DRAINAGE


Boulder Creek
Copper Creek
Sample Site B